

REVERSE CIRCULATION DIRECTIONAL AND HORIZONTAL DRILLING USING CONCENTRIC COIL TUBING

Field of the Invention

The present invention relates generally to a drilling method and apparatus for exploration and production of oil, natural gas, coal bed methane, methane hydrates, and the like. More particularly, the present invention relates to a concentric coiled tubing drill string drilling method and apparatus useful for reverse circulation drilling of directional and horizontal wellbores.

Background of the Invention

Drilling for natural gas, oil, or coalbed methane is conducted in a number of different ways. In conventional overbalanced drilling, a weighted mud system is pumped through a length of jointed rotating pipe, or, in the case of coiled tubing, through a length of continuous coiled tubing, and positive displacement mud motor is used to drive a drill bit to drill a borehole. The drill cuttings and exhausted pumped fluids are returned up the annulus between the drill pipe or coiled tubing and the walls of the drilled formation. Damage to the formations, which can prohibit their ability to produce oil, natural gas, or coalbed methane, can occur by filtration of the weighted mud system into the formation due to the hydrostatic head of the fluid column exceeding the pressure of the formations being drilled. Damage may also occur from the continued contact of the drilled formation with drill cuttings that are returning to surface with the pumped fluid.

Underbalanced drilling systems have been developed which use a mud or fluid system that is not weighted and under pumping conditions exhibit a hydrostatic head less than the formations being drilled. This is most often accomplished by pumping a commingled stream of liquid and gas as the drilling fluid. This allows the formations to flow into the wellbore while drilling, thereby reducing the damage to the formation. Nevertheless, some damage may still occur due to the continued contact

between the drill cuttings and exhausted pumped fluid that are returning to surface through the annulus between the drill string or coiled tubing and the formation.

5 Air drilling using an air hammer or rotary drill bit can also cause formation damage when the air pressure used to operate the reciprocating air hammer or rotary drill bit exceeds formation pressure. As drill cuttings are returned to surface on the outside of the drill string using the exhausted air pressure, damage to the formation can also occur.

10 Formation damage is becoming a serious problem for exploration and production of unconventional petroleum resources. For example, conventional natural gas resources are deposits with relatively high formation pressures. Unconventional natural gas formations such as gas in low permeability or "tight" reservoirs, coal bed methane, and shale gases have much lower pressures. Therefore, such formations
15 would damage much easier when using conventional oil and gas drilling technology.

Directional and horizontal drilling technology using a single coiled tubing drill string is known in the art. Thus, downhole tools useful for directional and horizontal drilling using coiled tubing are readily available. For example, coiled tubing drilling
20 operations use existing technologies for directional measurement systems and orientation of the drilling assembly, but because such devices are being used with single strings of coiled tubing, drilling fluids are pumped down the coiled tubing and returned up the annulus between the coiled tubing and the wellbore wall.

25 In Canadian Patent # 2,079,071 and US Patent # 5,215,151, issued to Smith and Goodman, incorporated herein by reference, a directionally drilling method is taught using coiled tubing which involves connection of a directional bottom hole assembly to a single string of coiled tubing. The directional bottom hole assembly is in electrical communication with existing directional drilling downhole sensors by
30 means of an electric cable inside the coiled tubing. The downhole sensors are coupled with a device for orienting or rotating the bottom hole assembly by way of fluid pressure or fluid rate variations. This drilling technology can be used in underbalanced drilling operations.

US Patent No. 5,394,951, issued to Pringle et al, incorporated herein by reference, teaches a method of directional drilling with coiled tubing using a commercially available electrical steering tool, mud-pulse and/or electromagnetic measurement-while-drilling (MWD) equipment. Further, Canadian Patent No. 2,282,342, issued to Ravensbergen et al, incorporated herein by reference, defines a bottom hole assembly for directional drilling with coiled tubing which includes electrically operated downhole data sensors and an electrically operated orientor for steering capabilities while drilling.

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Common to all the above referenced patents is the use of a single string of coiled tubing with a single path of flow within the coiled tubing. These patents further establish the existence of directional drilling capabilities on coiled tubing, with some reference to underbalanced drilling operations. The present invention extends the application of these existing technologies to concentric coiled tubing operations with reverse circulation of drill cuttings and formation fluids so as to avoid prolonged contact of these materials and associated damage with the formation. The present invention uses existing coiled tubing directional drilling technologies modified to provide for reverse circulation of the drilling medium and produced fluids.

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The present invention reduces the amount of contact between the formation and drill cuttings which normally results when using air drilling, mud drilling, fluid drilling and underbalanced drilling by using a concentric coiled tubing string drilling system. Such a reduction in contact will result in a reduction in formation damage.

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Summary of the Invention

The present invention allows for the directional and horizontal drilling of hydrocarbon formations in a less damaging and safe manner. The invention works particularly well in under-pressured hydrocarbon formations where existing underbalanced technologies can damage the formation.

Directional and horizontal drilling technology for coiled tubing exist today and are

common operations. These operations use existing technologies for directional measurement systems and orientation of the drilling assembly, but are conducted on single strings of coiled tubing such that fluids are pumped down the coiled tubing and returned up the annulus between the coiled tubing and the wellbore wall. The present invention uses a two-string or concentric coiled tubing drill string allowing for drilling fluid and drill cuttings to be removed through the concentric coiled tubing drill string, instead of through the annulus between the drill string and the formation. The present invention uses existing coiled tubing directional drilling tools modified to provide for reverse circulation of the drilling medium and produced fluids. For example, an outer casing can be provided for encasing existing directional drilling tools such that an annulus is formed between the outer wall of the tool and the inside wall of the outer casing.

The use of coiled tubing instead of drill pipe provides the additional advantage of continuous circulation while drilling, thereby minimizing pressure fluctuations and reducing formation damage. When jointed rotary pipe is used, circulation must be stopped while making or breaking connections to trip in or out of the hole. Further, when using jointed pipe, at each connection, any gas phase in the drilling fluid tends to separate out of the fluid resulting in pressure fluctuations against the formation.

The present invention allows for a wellbore to be drilled directionally or horizontally, either from surface or from an existing casing set in the ground at some depth, using reverse circulation so as to avoid or minimize contact between drill cuttings and the formation that has been drilled. Thus, the present invention can be used to drill the entire wellbore or just a portion of the wellbore, as required. The wellbore may be drilled overbalanced or underbalanced with drilling medium comprising drilling mud, drilling fluid, gaseous drilling fluid such as compressed air or a combination of drilling fluid and gas. In any of these cases, the drilling medium is reverse circulated up the concentric coiled tubing drill string with the drill cuttings such that drill cuttings are not in contact with the formation. Where required for safety purposes, an apparatus is included in or on the concentric coiled tubing string which is capable of closing off flow from the inner string, the annulus between the outer string and the inner string, or both to safeguard against uncontrolled flow from the formation to surface.

The present invention has a number of advantages over conventional drilling technologies in addition to reducing drilling damage to the formation. The invention reduces the accumulation of drill cuttings in the deviated or horizontal section of the wellbore; it allows for gas zones to be easily identified; and multi-zones of gas in shallow gas wellbores can easily be identified without significant damage during drilling.

The present invention is also useful for well stimulation. Hydraulic fracturing has been one of the most common methods of well stimulation in the oil and gas industry. This method of stimulation is not as effective in low and under pressure reservoirs. Five types of reservoir damage can occur in low and under pressure reservoirs when hydraulic fracturing is used, namely:

1. the pore throats in the rock plug up due to the movement of secondary clays;
2. fracturing gel, fracturing sand and fracturing acid compounds remain in the reservoir;
3. swelling of smectitic clays;
4. chemical additives cause precipitation of minerals and compounds in the reservoir; and
5. improper clean out of wellbore to remove materials from deviated section of the wellbore can cause serious damage to producing reservoirs.

Accessing natural fractures is one of the most important parts of completing any well in the oil and gas industry, and this is critical to the success of a low or under pressure well. Studies conducted by the United States Department of Energy showed that in a blanket gas reservoir on average a vertical drilled well encounters one fracture, a deviated drilled well encounters fifty-two fractures and a horizontally drilled well thirty-seven fractures.

Use of the reverse circulation drilling method and apparatus for forming directional and horizontal wells provides the necessary stimulation of the well without the damage caused by hydraulic fracturing.

Thus, the present invention allows low and under pressure formations or reservoirs to receive the necessary well stimulation with out damage that is usually encountered using hydraulic fracturing.

5 In accordance with one aspect of the invention, a method for drilling a directional or horizontal wellbore in a hydrocarbon formation is provided herein, comprising the steps of:

- 10 • providing a concentric coiled tubing drill string having an inner coiled tubing string, said inner coiled tubing string having an inside wall and an outside wall and situated within an outer coiled tubing string having an inside wall and an outside wall, said outside wall of said inner coiled tubing string and said inside wall of said outer coiled tubing string defining an annulus between the coiled tubing strings;
- 15 • connecting a bottomhole assembly comprising a directional drilling means to the concentric coiled tubing drill string; and
- delivering drilling medium through one of said annulus or inner coiled tubing drill string for operating the directional drilling means to form a directional or horizontal borehole and removing exhaust drilling medium by extracting
20 exhaust drilling medium through said other of said annulus or inner coiled tubing string.

The coiled tubing strings may be constructed of steel, fiberglass, composite material, or other such material capable of withstanding the forces and pressures of the
25 operation. The coiled tubing strings may be of consistent wall thickness or tapered.

In one embodiment of the drilling method, the exhaust drilling medium is delivered through the annulus and removed through the inner coiled tubing string. The exhaust drilling medium comprises any combination of drill cuttings, drilling medium
30 and hydrocarbons.

In another embodiment, the flow paths may be reversed, such that the drilling medium is pumped down the inner coiled tubing string to drive the directional drilling

means and exhaust drilling medium, comprising any combination of drilling medium, drill cuttings and hydrocarbons, is extracted through the annulus between the inner coiled tubing string and the outer coiled tubing string.

- 5 The drilling medium can comprise a liquid drilling fluid such as, but not limited to, water, diesel, or drilling mud, or a combination of liquid drilling fluid and gas such as, but not limited to, air, nitrogen, carbon dioxide, and methane, or gas alone. The drilling medium is pumped down the annulus to the directional drilling means to drive the directional drilling means.

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Examples of suitable directional drilling means comprise a reverse-circulating mud motor with a rotary drill bit, or a mud motor with a reverse circulating drilling bit. When the drilling medium is a gas, a reverse circulating air hammer or a positive displacement air motor with a reverse circulating drill bit can be used. The directional drilling means further comprises a bent sub or bent housing which provides a degree of misalignment of the lower end of the directional drilling means relative to the upper end of the directional drilling means. This degree of misalignment results in the drilling of new formation in a direction other than straight ahead.

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In a preferred embodiment, the directional drilling means further comprises a diverter means such as, but not limited to, a venturi or a fluid pumping means, which diverts or draws the exhaust drilling medium, the drill cuttings, and any hydrocarbons back into the inner coiled tubing string where they are flowed to surface. This diverter means may be an integral part of the directional drilling means or a separate apparatus.

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In a preferred embodiment, the bottomhole assembly further comprises an orientation means such as, but not limited to, an electrically or hydraulically operated rotation device capable of rotating the directional drilling means so as to orientate the direction of the wellbore to be drilled.

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The orientation means can operate in a number of different ways, including, but not

limited to:

1. providing an electrical cable which runs inside the inner coiled tubing string from surface to the end of the concentric string, such that the orienting means is in electrical communication with a surface control means;
- 5 2. providing a plurality of small diameter capillary tubes which run inside the inner coiled tubing string from surface to the end of the concentric string, such that the orienting means is in hydraulic communication with a surface control means

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In a preferred embodiment, the bottomhole assembly further comprises a downhole data collection and transmission means such as, but not limited to, a measurement while drilling tool or a logging while drilling tool, or both. Such tools provide a number of parameters, including, but not limited to, azimuth, inclination, magnetics,
15 vibration, pressure, orientation, gamma radiation, and fluid resistivity.

The downhole data collection and transmission means can operate in a number of different ways, including, but not limited to:

- 20 1. providing an electrical cable which runs inside the inner coiled tubing string from surface to the end of the concentric string, such that the downhole data collection and transmission means is in electrical communication with a surface data collection and transmission means;
2. providing a plurality of small diameter capillary tubes which run inside the
25 inner coiled tubing string from surface to the end of the concentric string, such that the downhole data collection and transmission means is in hydraulic communication with a surface data collection and transmission means;
3. providing a plurality of fiber optic cables which run inside the inner coiled
30 tubing string from surface to the end of the concentric string, such that the downhole data collection and transmission means is in communication with a surface data collection and transmission means by way of light pulses or signals; and

4. providing a radio frequency or electromagnetic transmitting device located at within the downhole data collection and transmission means which communicates to a receiving device situated in a surface data collection and transmission means.

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When used in conjunction with the orienting means and the downhole data and transmission means, the directional drilling means allows for the steering of the well trajectory in a planned or controlled direction.

- 10 The method for drilling a directional or horizontal wellbore can further comprise the step of providing a downhole flow control means attached to the concentric coiled tubing drill string near the directional drilling means for preventing any flow of hydrocarbons to the surface from the inner coiled tubing string or the annulus or both when the need arises. The downhole flow control means is capable of shutting off
15 flow from the wellbore through the inside of the inner coiled tubing string, through the annulus between the inner coiled tubing string and the outer coiled tubing string, or through both.

The downhole flow control means can operate in a number of different ways,
20 including, but not limited to:

1. providing an electrical cable which runs inside the inner coiled tubing string from surface to the end of the concentric string, such that the downhole flow control means is activated by a surface control means which transmits an
25 electrical charge or signal to an actuator at or near the downhole flow control means;
2. providing a plurality of small diameter capillary tubes which run inside the inner coiled tubing string from surface to the end of the concentric string, such that the downhole flow control means is activated by a surface control means
30 which transmits hydraulic or pneumatic pressure to an actuator at or near the downhole flow control means;
3. providing a plurality of fiber optic cables which run inside the inner coiled tubing string from surface to the end of the concentric string, such that the

downhole flow control means is activated by a surface control means which transmits light pulses or signals to an actuator at or near the downhole flow control means; and

4. providing a radio frequency transmitting device located at surface that actuates a radio frequency receiving actuator located at or near the downhole flow control means.

In another preferred embodiment, the method for drilling a directional or horizontal wellbore can further comprise the step of providing a surface flow control means for preventing any flow of hydrocarbons from the space between the outside wall of the outer coiled tubing string and the walls of the formation or wellbore. The surface flow control means may be in the form of annular bag blowout preventors, which seal around the outer coiled tubing string when operated under hydraulic pressure, or annular ram or closing devices, which seal around the outer coiled tubing string when operated under hydraulic pressure, or a shearing and sealing ram which cuts through both strings of coiled tubing and closes the wellbore permanently. The specific design and configuration of these surface flow control means will be dependent on the pressure and content of the wellbore fluid, as determined by local law and regulation.

In another preferred embodiment, the method for drilling a directional or horizontal wellbore further comprises the step of reducing the surface pressure against which the inner coiled tubing string is required to flow by means of a surface pressure reducing means attached to the inner coiled tubing string. The surface pressure reducing means provides some assistance to the flow and may include, but not be limited to, a suction compressor capable of handling drilling mud, drilling fluids, drill cuttings and hydrocarbons installed on the inner coiled tubing string at surface.

In another preferred embodiment, the method for drilling a directional or horizontal wellbore further comprises the step of directing the extracted exhaust drilling medium to a discharge location sufficiently remote from the wellbore to provide for well site safety. This can be accomplished by means of a series of pipes, valves and rotating pressure joint combinations so as to provide for safety from combustion of any

produced hydrocarbons. Any hydrocarbons present in the exhaust drilling medium can flow through a system of piping or conduit directly to atmosphere, or through a system of piping and/or valves to a pressure vessel, which directs flow from the well to a flare stack or riser or flare pit.

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The present invention further provides an apparatus for drilling a directional or horizontal wellbore in hydrocarbon formations, comprising:

- 10 • a concentric coiled tubing drill string having an inner coiled tubing string having an inside wall and an outside wall and an outer coiled tubing string having an inside wall and an outside wall, said outside wall of said inner coiled tubing string and said inside wall of said outer coiled tubing string defining an annulus between the coiled tubing strings;
- 15 • a bottomhole assembly comprising a directional drilling means operably connected to said concentric coiled tubing drill string; and
- 20 • a drilling medium delivery means for delivering drilling medium through one of said annulus or inner coiled tubing string for operating the directional drilling means to form said directional or horizontal wellbore and for removing exhaust drilling medium through said other of said annulus or inner coiled tubing string.

The drilling medium can be air, drilling mud, drilling fluids, gases or various combinations of each.

25 In a preferred embodiment, the apparatus further comprises a downhole flow control means positioned near the directional drilling means for preventing flow of hydrocarbons from the inner coiled tubing string or the annulus or both to the surface of the wellbore.

30 In a further preferred embodiment, the apparatus further comprises a surface flow control means for preventing any flow of hydrocarbons from the space between the outside wall of the outer coiled tubing string and the walls of the wellbore.

In another preferred embodiment, the apparatus further comprises means for connecting the outer coiled tubing string and the inner coiled tubing string to the bottomhole assembly. The connecting means centers the inner coiled tubing string within the outer coiled tubing string, while still providing for isolation of flow paths
5 between the two coiled tubing strings. In normal operation the connecting means would not allow for any movement of one coiled tubing string relative to the other, however may provide for axial movement or rotational movement of the inner coiled tubing string relative to the outer coiled tubing string in certain applications. The connecting means also provides for the passage of capillary tubes or capillary tube
10 pressures, electric cable or electrical signals, fibre optics or fibre optic signals, or other such communication methods for the operation of a downhole data collection and transmission means and the orientation means, plus other devices as may be necessary or advantageous for the operation of the apparatus.

15 In another preferred embodiment, the apparatus further comprises a disconnecting means located between the connecting means and the directional drilling means, to provide for a way of disconnecting the directional drilling means from the concentric coiled tubing drill string. The means of operation can include, but not be limited to, electric, hydraulic, or shearing tensile actions.

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In another preferred embodiment, the apparatus further comprises a rotation means attached to the directional drilling means when said directional drilling means comprising an reciprocating air hammer and a drilling bit. This is seen as a way of improving the cutting action of the drilling bit.

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In a preferred embodiment, the bottomhole assembly further comprises one or more tools selected from the group consisting of a downhole data collection and transmission means, a shock sub, a drill collar, a downhole flow control means and a interchange means.

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In a preferred embodiment, the downhole data collection and transmission means comprises a measurement-while-drilling tool or a logging-while-drilling tool or both.

In another preferred embodiment, the apparatus further comprises means for storing the concentric coiled tubing drill string such as a work reel. The storage means may be integral to the coiled tubing drilling apparatus or remote, said storage means being fitted with separate rotating joints dedicated to each of the inner coiled tubing string and annulus. These dedicated rotating joints allow for segregation of flow between the inner coiled tubing string and the annulus, while allowing rotation of the coiled tubing work reel and movement of the concentric coiled tubing string in and out of the wellbore. The said storage means is also fitted with pressure control devices or bulkheads which allow the insertion of electric cable, capillary tubes, fibre optic cables, and other such communication means into the inner or outer coiled tubing strings while under pressure but allowing access to such communicating means at surface for surface operation of the downhole devices.

Brief Description of the Drawings

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Figure 1a is a vertical cross-section of a section of concentric coiled tubing drill string and bottomhole assembly for directional and horizontal drilling.

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Figure 1b is a vertical cross-section of a section of concentric coiled tubing drill string and bottomhole assembly having an interchange means for directional and horizontal drilling.

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Figure 2 is a general view showing a partial cross-section of the apparatus and method of the present invention as it is located in a drilling operation.

Figure 3 is a schematic drawing of the operations used for the removal of exhaust drilling medium out of the wellbore.

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Figure 4a shows a vertical cross-section of a downhole flow control means in the open position.

Figure 4b shows a vertical cross-section of a downhole flow control means in the

closed position.

Figure 5 shows a vertical cross-section of a concentric coiled tubing connector.

- 5 Figure 6 is a schematic drawing of a concentric coiled tubing bulkhead assembly.

Description of the Preferred Embodiments

- Figure 1a is a vertical cross-section of concentric coiled tubing drill string 03 and
10 bottomhole assembly 22 useful for reverse circulation drilling of a directional or horizontal wellbore in hydrocarbon formations according to the present invention. In this embodiment, all bottomhole tools which comprise the bottomhole assembly 22 have been adapted for use with concentric coiled tubing and reverse circulation drilling. For example, an outer casing can be provided for encasing existing drilling
15 tools for single coiled tubing, thereby providing an annulus between the outer wall of the drilling tool and the inner wall for the outer casing.

- Concentric coiled tubing drill string 03 comprises an inner coiled tubing string 01 having an inside wall 70 and an outside wall 72 and an outer coiled tubing string 02
20 having an inside wall 74 and an outside wall 76. The inner coiled tubing string 01 is inserted inside the outer coiled tubing string 02. The outer coiled tubing string 02 typically has an outer diameter of 73.0mm or 88.9mm, and the inner coiled tubing string 01 typically has an outer diameter of 38.1mm, 44.5mm, or 50.8mm. Other diameters of either string may be run as deemed necessary for the operation.
25 Concentric coiled tubing drill string annulus 30 is formed between the outside wall 72 of the inner coiled tubing string 01 and the inside wall 74 of the outer coiled tubing string 02.

- Concentric coiled tubing drill string 03 is connected to bottom hole assembly 22, said
30 bottom hole assembly 22 comprising a reverse-circulating directional drilling means 04. Bottomhole assembly 22 further comprises concentric coiled tubing connector 06 and, in preferred embodiments, further comprises a downhole blowout preventor or flow control means 07, orientation means 60, disconnecting means 08, and

downhole data collection and transmission means 62. Reverse-circulating directional drilling means 04 comprises bent sub or bent housing 64, rotating sub 09, reverse circulating impact hammer 80, and impact or drilling bit 78.

- 5 Bent sub or bent housing 64 provides a degree of misalignment of the directional drilling assembly 04 from the previously drilled hole. The bent sub or bent housing 64 is fixed in the string relative to a known reference angle in the downhole data collection and transmission means 62 such that the downhole data collection and transmission means is capable of communicating the orientation of the bent sub to a
- 10 surface data control system through electric wireline 66. Orientation means 60 is used to provide a degree of rotation of the bent sub 64 to control the angle of misalignment of the bent sub 64. Orientation means 60 is operated by electrical communication with a surface control means through electric wireline 66.
- 15 Rotating sub 09 rotates reverse circulating impact hammer 80 and drilling bit 78 to ensure it doesn't strike at only one spot in the wellbore. Disconnecting means 08 provides a means for disconnecting concentric coiled tubing drill string 03 from the reverse-circulation drilling means 04 should it get stuck in the wellbore. Downhole flow control means 07 enables flow from the wellbore to be shut off through either or
- 20 both of the inner coiled tubing string 01 and the concentric coiled tubing drill string annulus 30 between the inner coiled tubing string 01 and the outer coiled tubing string 02. Concentric coiled tubing connector 06 connects outer coiled tubing string 02 and inner coiled tubing string 01 to the bottom hole assembly 22.
- 25 Flow control means 07 operates by means of two small diameter capillary tubes 10 that are run inside inner coiled tubing string 01 and connect to closing device 07. Hydraulic or pneumatic pressure is transmitted through capillary tubes 10 from surface. Capillary tubes 10 are typically stainless steel of 6.4mm diameter, but may be of varying material and of smaller or larger diameter as required.
- 30 Drilling medium 28 is pumped through concentric coiled tubing drill string annulus 30, through the bottomhole assembly 22, and into a flow path 36 in the reverse-circulating drilling means 04, while maintaining isolation from the inside of the inner

coiled tubing string 01. The drilling fluid 28 powers the reverse-circulating drilling means 04, which drills a hole in the casing 32, cement 33, and/or hydrocarbon formation 34 resulting in a plurality of drill cuttings 38.

5 Exhaust drilling medium 35 from the reverse-circulating drilling means 04 is, in whole or in part, drawn back up inside the reverse-circulating drilling assembly 04 through a flow path 37 which is isolated from the drilling fluid 28 and the flow path 36. Along with exhaust drilling medium 35, drill cuttings 38 and formation fluids 39 are also, in whole or in part, drawn back up inside the reverse-circulating drilling assembly 04
10 and into flow path 37. Venturi 82 aids in accelerating exhaust drilling medium 35 to ensure that drill cuttings are removed from downhole. Shroud 84 is located between impact hammer 80 and inner wall 86 of wellbore 32 in relatively air tight and frictional engagement with the inner wall 86. Shroud 84 reduces exhaust drilling medium 35 and drill cuttings 38 from escaping up the wellbore annulus 88 between the outside
15 wall 76 of outer coiled tubing string 02 and the inside wall 86 of wellbore 32 so that the exhaust drilling medium, drill cuttings 38, and formation fluids 39 preferentially flow up the inner coiled tubing string 01. Exhaust drilling medium 35, drill cuttings 38, and formation fluids 39 from flow path 37 are pushed to surface under formation pressure.

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In another embodiment of the present invention, drilling medium can be pumped down inner coiled tubing string 01 and exhaust drilling medium carried to the surface of the wellbore through concentric coiled tubing drill string annulus 30. Reverse circulation of the present invention can use as a drilling medium air, drilling muds or
25 drilling fluids or a combination of drilling fluid and gases such as nitrogen and air.

Figure 1b shows another preferred embodiment which uses conventional drilling tools used with single coiled tubing. In this embodiment, bottomhole assembly 22 comprises an interchange means 67 for diverting drill cuttings 38 from the wellbore
30 annulus 88 into the inner coiled tubing string 01. Interchange means 67 comprises vertical slot 68 to let drill cuttings 38 escape through the center of inner coiled tubing string 01. Interchange means 67 further comprises wings or shroud 69 which prevents drill cuttings 38 from continuing up the wellbore annulus to the surface of

the wellbore. Generally, if the wellbore being drilled is 6 ¼ inches in diameter, the outer diameter (OD) of the interchange means 67 would be 5 ½ inches, which would include the wings or shroud 69.

5 Figure 2 shows a preferred embodiment of the present method and apparatus for safely drilling a natural gas well or any well containing hydrocarbons horizontally or directionally using concentric coiled tubing drilling. Concentric coiled tubing drill string 03 is run over a gooseneck or arch device 11 and stabbed into and through an injector device 12. Arch device 11 serves to bend concentric coiled tubing string 03
10 into injector device 12, which serves to push the concentric coiled tubing drill string into the wellbore, or pull the concentric coiled tubing string 03 from the wellbore as necessary to conduct the operation. Concentric coiled tubing drill string 03 is pushed or pulled through a stuffing box assembly 13 and into a lubricator assembly 14. Stuffing box assembly 13 serves to contain wellbore pressure and fluids, and
15 lubricator assembly 14 allows for a length of coiled tubing or bottomhole assembly 22 to be lifted above the wellbore and allowing the wellbore to be closed off from pressure.

As was also shown in Figure 1, bottom hole assembly 22 is connected to the
20 concentric coiled tubing drill string 03. Typical steps would be for the bottomhole assembly 22 to be connected to the concentric coiled tubing drill string 03 and pulled up into the lubricator assembly 14. The bottomhole assembly comprises a bent sub or housing and the angle of the bent sub or housing relative to the reference angle of measurement within the downhole data collection and transmission means is
25 determined, and provides a corrected reference measurement for all subsequent downhole measurements of the orientation of the bent sub or housing. Lubricator assembly 14 is manipulated in an upright position directly above the wellhead 16 and surface blowout preventor 17 by means of crane 18 with a cable and hook assembly 19. Lubricator assembly 14 is attached to surface blowout preventor 17 by a quick-
30 connect union 20. Lubricator assembly 14, stuffing box assembly 13, and surface blowout preventor 17 are pressure tested to ensure they are all capable of containing expected wellbore pressures without leaks. Downhole flow control means 07 is also tested to ensure it is capable of closing from surface actuated controls (not shown)

and containing wellbore pressure without leaks.

- Surface blowout preventor 17 is used to prevent a sudden or uncontrolled flow of hydrocarbons from escaping from the wellbore annulus 88 between the inner wellbore wall 86 and the outside wall 76 of the outer coiled tubing string 02 during the drilling operation. An example of such a blowout preventor is Texas Oil Tools Model # EG72-T004. Surface blowout preventor 17 is not equipped to control hydrocarbons flowing up the inside of concentric coiled tubing drill string, however.
- Figure 3 is a schematic drawing of the operations used for the removal of exhaust drilling medium out of the wellbore. Suction compressor 41 or similar device may be placed downstream of the outlet rotating joint 40 to maintain sufficient fluid velocity inside the inner coiled tubing string 01 to keep all solids moving upwards and flowed through an outlet rotating joint 40. This is especially important when there is insufficient formation pressure to move exhaust medium 35, drill cuttings 38, and formation fluids 39 up the inner space of the inner coiled tubing string 01. Outlet rotating joint 40 allows exhaust medium 35, drill cuttings 38, and formation fluids 39 to be discharged from the inner space of inner coiled tubing string 01 while maintaining pressure control from the inner space, without leaks to atmosphere or to concentric coiled tubing drill string annulus 30 while moving the concentric coiled tubing drill string 03 into or out of the wellbore.

- Upon completion of pressure testing, wellhead 16 is opened and concentric coiled tubing drill string 03 and bottom hole assembly 22 are pushed into the wellbore by the injector device 12. A hydraulic pump 23 may pump drilling mud or drilling fluid 24 from a storage tank 25 into a flow line T-junction 26. In the alternative, or in combination, air compressor or nitrogen source 21 may also pump air or nitrogen 27 into a flow line to T-junction 26. Therefore, drilling medium 28 can consist of drilling mud or drilling fluid 24, gas 27, or a commingled stream of drilling fluid 24 and gas 27 as required for the operation.

Drilling medium 28 is pumped into the inlet rotating joint 29 which directs drilling medium 28 into concentric coiled tubing drill string annulus 30 between inner coiled

tubing string 01 and outer coiled tubing string 02. Inlet rotating joint 29 allows drilling medium 28 to be pumped into concentric coiled tubing drill string annulus 30 while maintaining pressure control from concentric coiled tubing drill string annulus 30, without leaks to atmosphere or to inner coiled tubing string 01, while moving
5 concentric coiled tubing drill string 03 into or out of the wellbore.

Exhaust drilling medium 35, drill cuttings 38, and formation fluids 39 flow from the outlet rotating joint 40 through a plurality of piping and valves 42 to a surface separation system 43. Surface separation system 43 may comprise a length of
10 straight piping terminating at an open tank or earthen pit, or may comprise a pressure vessel capable of separating and measuring liquid, gas, and solids. Exhaust medium 35, drill cuttings 38, and formation fluids 39, including hydrocarbons, that are not drawn into the reverse-circulation drilling assembly may flow up the wellbore annulus 88 between the outside wall 76 of outer coiled tubing
15 string 02 and the inside wall 86 of wellbore 32. Materials flowing up the wellbore annulus 88 will flow through wellhead 16 and surface blowout preventor 17 and be directed from the blowout preventor 17 to surface separation system 43.

Figure 4a is a vertical cross-section of downhole flow control means 07 in open position and Figure 4b is a vertical cross-section of downhole flow control means 07
20 in closed position. Downhole flow control means 07 may be required within motor head assembly 05 to enable flow from the wellbore to be shut off through either or both of the inner coiled tubing string 01 or the concentric coiled tubing drill string annulus 30. For effective well control, the closing device should be capable of being
25 operated from surface by a means independent of the wellbore conditions, or in response to an overpressure situation from the wellbore.

Referring first to Figure 4a, the downhole flow control means 07 allows drilling medium 28 to flow through annular flow path 36. Drilling medium from the annular
30 flow path 36 is directed in first diffuser sub 92 that takes the annular flow path 36 and channels it into single monobore flow path 94. Drilling medium 28 flows through single monobore flow path 94 and through a check valve means 96 which allows flow in the intended direction, but operates under a spring mechanism to stop flow

- from reversing direction and traveling back up the annular flow path 36 or the single monobore flow path 94. Downstream of check valve means 96 single monobore flow path 94 is directed through second diffuser sub 98 which re-directs flow from single monobore flow path 94 back to annular flow path 36. When operated in the open position, exhaust drilling medium 35, drill cuttings 38 and formation fluid 39, including hydrocarbons, flow up through inner coiled tubing flow path 37. Inner coiled tubing flow path 37 passes through hydraulically operated ball valve 100 that allows full, unobstructed flow when operated in the open position.
- 10 Referring now to Figure 4b, downhole flow control means 07 is shown in the closed position. To provide well control from inner coiled tubing flow path 37, hydraulic pressure is applied at pump 47 to one of capillary tubes 10. This causes ball valve 100 to close thereby closing off inner coiled tubing flow path 37 and preventing uncontrolled flow of formation fluids or gas through the inner coiled tubing string 01.
- 15 In the event of an overpressure situation in single monobore flow path 94, check valve 96 closes with the reversed flow and prevents reverse flow through single monobore flow path 94. In this embodiment, wellbore flow is thus prohibited from flowing up annular flow path 36 or single monobore flow path 94 in the event formation pressure exceeds pumping pressure, thereby providing well control in the annular flow path 36.
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An optional feature of downhole flow control means 07 would allow communication between single monobore flow path 94 and inner coiled tubing flow path 37 when the downhole flow control means is operated in the closed position. This would allow continued circulation down annular flow path 36 and back up inner coiled tubing flow path 37 without being open to the wellbore. It is understood that integral to flow control means 07 is the ability to provide passage of electrical signals from electric wireline 60 through flow control means 07 to orientation means 60 and the downhole data collection and transmission means, as shown in Figures 1a and 1b.

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Figure 5 is a vertical cross-section of concentric coiled tubing connector 06. Both outer coiled tubing string 02 and the inner coiled tubing string 01 are connected to bottom hole assembly by means of concentric coiled tubing connector 06. First

connector cap 49 is placed over outer coiled tubing string 02. First external slip rings 50 are placed inside first connector cap 49, and are compressed onto outer coiled tubing string 02 by first connector sub 51, which is threaded into first connector cap 49. Inner coiled tubing string 01 is extended through the bottom of first connector sub 51, and second connector cap 52 is placed over inner coiled tubing string 01 and threaded into first connector sub 51. Second external slip rings 53 are placed inside second connector cap 52, and are compressed onto inner coiled tubing string 01 by second connector sub 54, which is threaded into second connector cap 52. First connector sub 51 is ported to allow flow through the sub body from concentric coiled tubing drill string annulus 30.

Figure 6 is a schematic diagram of a coiled tubing bulkhead assembly. Drilling medium 28 is pumped into rotary joint 29 to first coiled tubing bulkhead 55, which is connected to the concentric coiled tubing drill string 03 by way of outer coiled tubing string 02 and ultimately feeds concentric coiled tubing drill string annulus 30. First coiled tubing bulkhead 55 is also connected to inner coiled tubing string 01 such that flow from the inner coiled tubing string 01 is isolated from concentric coiled tubing drill string annulus 30. Inner coiled tubing string 01 is run through a first packoff device 56 which removes it from contact with concentric coiled tubing drill string annulus 30 and connects it to second coiled tubing bulkhead 57. Flow from inner coiled tubing string 01 flows through second coiled tubing bulkhead 57, through a series of valves, and ultimately to outlet rotary joint 40, which permits flow from inner coiled tubing string 01 under pressure while the concentric coiled tubing drill string 03 is moved into or out of the well. Flow from inner coiled tubing string 01, which comprises exhaust drilling medium 35, drill cuttings 38 and formation fluid 39, including hydrocarbons, is therefore allowed through outlet rotary joint 40 and allowed to discharge to the surface separation system.

An additional feature of second coiled tubing bulkhead 57 is that it provides for the insertion of an electric cable and one or more smaller diameter tubes or devices, with pressure control, into the inner coiled tubing string 01 through second packoff 58. In the preferred embodiment, second packoff 58 provides for two capillary tubes 10 to be run inside the inner coiled tubing string 01 for the operation and control of

downhole flow control means 07, the orientation means 60, or both. It further provides for an electric wireline 66 to be run inside the inner coiled tubing string 01 for the operation and control of the orientation means 60, the downhole data collection and transmission means 62, or both. The capillary tubes 10 and electric
5 wireline 66 are connected to a third rotating joint 59, allowing pressure control of the capillary tubes 10 and electric wireline 66 while rotating the work reel.

While various embodiments in accordance with the present invention have been shown and described, it is understood that the same is not limited thereto, but is
10 susceptible of numerous changes and modifications as known to those skilled in the art, and therefore the present invention is not to be limited to the details shown and described herein, but intend to cover all such changes and modifications as are encompassed by the scope of the appended claims.

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